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RESEARCH MEMORANDUM

EFFECTS OF EXTERNAL STORE MOUNTING ON THE BUFFET, TRIM, AND DRAG CHARACTERISTICS OF ROCKET-POWERED FUSELAGE AND STORE COMBINATIONS BETWEEN MACH NUMBERS OF 0.7 AND 1.4

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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EFFECTS OF EXTERNAL STORE MOUNTING ON THE BUFFET, TRIM, AND DRAG CHARACTERISTICS OF ROCKET-POWERED FUSELAGE AND STORE COMBINATIONS BETWEEN MACH NUMBERS OF 0.7 AND 1.4

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SUMMARY

An investigation has been made of the effects of store mounting on the buffet, trim, and drag characteristics of fuselage-mounted external stores between Mach numbers of 0.7 and 1.4 by the use of the rocket-propelled-model technique. Four models have been tested which consisted of wingless parabolic fuselages with finless models of a 10,000-pound large-diameter bomb located at the same longitudinal stations with various store mounting arrangements. The mounting arrangements tested were a semisubmerged store, a store mounted tangent to the fuselage, a store mounted on a 10-percent-thick pylon, and a store mounted on a 4-percent-thick pylon. In conjunction with these tests, a model has been flown by the helium-gun technique to obtain the drag of the isolated store.

Results of these tests are presented as the incremental accelerations in the stores due to buffeting, trim normal- and side-force coefficients, tail helix angles, and drag coefficients plotted against Mach number. Data from these tests indicate that low-lift high-speed buffeting may be induced by interference effects around completely external fuselage-mounted stores and that the buffet and drag characteristics of such configurations may be adversely affected by fuselage-store proximity and pylon thickness. It is shown that the semisubmerged store arrangement of the particular fuselage and store used in these tests was optimum from the standpoint of both buffeting and drag; whereas the store mounted tangent to the fuselage produced more severe effects than did pylon-mounted stores. Buffeting due to interference is shown to persist to supersonic Mach numbers. No severe or abrupt trim changes may be attributed to the stores tested, although a positive trend in trim normal force is evidenced at subsonic Mach numbers.

INTRODUCTION

The use of external fuel tanks and externally mounted bomb loads has given rise to several problems, among which two of the most important are a lowering of the airplane buffet boundary and an increase in drag. In some cases buffet intensity has been increased because of external stores. Inasmuch as most external stores have been located at various positions on the airplane wing, locating the external stores on the fuselage offers a possible partial solution to the buffeting and drag problems. An investigation has been made to determine the buffet and drag characteristics of fuselage-mounted external stores on a wingless configuration, by the use of the rocket-propelled-model technique, with particular attention to determining the optimum store mounting arrangement. Presented herein are the results of flight tests of four configurations having models of a 10,000-pound large-diameter bomb mounted on the fuselage of a wingless configuration.

SYMBOLS

A	cross-sectional area, sq ft
A_{max}	maximum total cross-sectional area of configuration, sq ft
A_s	maximum cross-sectional area of store, sq ft
Δa_t	increment of transverse acceleration, g units
b	tail surface span, ft
C_D	total drag coefficient, Drag/qA
ΔC_D	$\dfrac{\text{Drag with store - Drag without store}}{qA_s}$
C_N	normal-force coefficient, Normal force/qS
C_Y	side-force coefficient, Side force/qS
L	fuselage length, ft
M	Mach number

p rate of roll, radians/sec

$\left(\frac{pb}{2V}\right)_T$ helix angle of tail, radians

q dynamic pressure, lb/sq ft

R Reynolds number based on fuselage length

S total area in one plane of tail, sq ft

MODELS

The fuselage used in this investigation was the basic parabolic body discussed in reference 1. The store used was a model of a 10,000-pound large-diameter bomb without fins. The ratio of store diameter to fuselage diameter was 0.588 and the maximum store diameter was located at 50 percent of the fuselage length. Fuselage and store coordinates are shown in table I. Principal dimensions and the longitudinal distribution of cross-sectional area are shown in figures 1 and 2, respectively. Photographs of each store configuration are shown as figure 3. Tail surfaces of all models were unswept, of aspect ratio 4, of taper ratio 0.6, and had NACA 65A006 airfoil sections parallel to the model center line. Tail surfaces were rotated 45° with respect to a plane through the fuselage and store center lines.

Configurations tested were: a semisubmerged store (model A), a store mounted tangent to the fuselage (model B), a pylon-mounted store - NACA 66A010 pylon section (model C), and a pylon-mounted store - 4-percent-thick modified-flat-plate pylon section (model D). All stores used in these tests were constructed of balsa wood, Fiberglas, and plastic for maximum rigidity and minimum weight. The 10-percent-thick pylon was constructed of laminated spruce with $\frac{1}{32}$-inch steel surface inlay. The 4-percent-thick pylon was solid steel with beveled leading and trailing edges with all surface discontinuities hand faired. The length of each pylon was one-half the store diameter, and the chord was one-fourth the store length. The weights of models for which accelerations are presented were: with tangent-mounted store, 67 pounds; with pylon-mounted store (10-percent pylon), 63.7 pounds; with pylon-mounted store (4-percent pylon), 66.3 pounds.

A photograph of an isolated-store model used in conjunction with the present tests to determine the isolated-store drag is shown as figure 3(d). This model was a 0.34-scale model of the store used in the present tests with stabilizing fins added.

INSTRUMENTATION

All models tested in this series incorporated normal and transverse accelerometers in the fuselage near the root quarter chord of the tail surfaces and a longitudinal accelerometer in the fuselage nose. Each of the models having completely external stores had normal and transverse accelerometers inside the store. The model having the semisubmerged store had a normal and a transverse accelerometer mounted in the fuselage nose. All accelerometers were referenced to the plane of the store and fuselage center lines. All normal and transverse accelerometers had natural frequencies of the order of 75 to 110 cps and 50 to 60 percent critical damping. These characteristics combined with the recorder characteristics to yield system amplitude response factors ranging from approximately 0.5 to 1.0 at frequencies ranging from 80 to 110 cps which were the predominant first-mode frequencies encountered in these tests in the transverse plane. The minimum identifiable buffet amplitudes detectable in these tests were estimated to be of the order of ±0.05g.

TESTS

Shake tests were conducted with each model to determine the approximate natural frequencies and modes of vibration, but the modes of vibration of the store assembly were extremely difficult to identify because of the structural rigidity of the models. Results of these shake tests in the transverse plane were as follows:

	Frequency
Tangent-mounted store	108 and 180 cps
Store on 10-percent-thick pylon	92 and 220 cps
Store on 4-percent-thick pylon	82, 126, and 150 cps

The lower store frequencies are believed to represent bending of the store mount, whereas the higher frequencies represent unidentified modes in mount bending, mount torsion, and store bending. A 220 cps frequency was observed when shaking in the normal plane also and is believed to have been store bending. Tail first-bending frequencies of all models were within the range of 115 to 130 cps.

Flight tests were conducted using external booster rocket motors and internal sustainer rocket motors to accelerate the models. Each model was launched from a rail-type launcher (fig. 4) and was accelerated to approximately $M = 1.1$ by the external booster, then, after a short coasting period, the sustainer rocket motor accelerated the model to approximately $M = 1.4$. The models then decelerated through the speed

range in free flight. The accelerometer data presented herein were measured during the coasting parts of each flight and transmitted to the ground and recorded by standard NACA telemetering equipment. Velocity was obtained from CW Doppler radar, flight-path data from SCR 584 tracking radar, and rate of roll from a spinsonde recorder and the model telemeter antennas. Atmospheric data were obtained from radiosondes released either just before or just after each flight. The scale of these tests is shown on figure 5 as Reynolds number, based on fuselage length, plotted against Mach number for each configuration. Figure 6 shows the variation of dynamic pressure, in pounds per square foot, with Mach number for all models.

The isolated-store model used in conjunction with the present investigation was flight tested using the helium-gun technique of reference 2. Flight tests were conducted by the Langley Pilotless Aircraft Research Station at Wallops Island, Va.

RESULTS AND DISCUSSION

Some effects of store mounting on the buffet, trim, and drag characteristics of a wingless configuration having fuselage-mounted models of a 10,000-pound large-diameter bomb without fins are presented herein.

Trim

The trim characteristics of each model are presented in figures 7 to 9 as normal-force coefficient C_N, side-force coefficient C_Y, and tail helix angle $(pb/2V)_T$ plotted against Mach number. No large or abrupt changes in trim C_N (fig. 7) were experienced in any of these tests. Perhaps the most interesting trim characteristic of these fuselage-mounted stores was a consistent tendency toward zero or positive trim normal force at subsonic speeds regardless of the type of store mount used and despite the negative moment due to the unsymmetrical drag of the stores. It is thought that this tendency was probably a result of a strong wake behind the stores passing near the tail surfaces. At about $M = 0.92$ this wake effect either decreased or its moment was overcome by the unsymmetrical drag of the store assembly; a condition resulting in a tendency toward negative supersonic trim normal force. The model having the tangent-mounted store and the model having the store on the thick pylon show the greatest tendency toward positive subsonic trim-normal-force coefficients. These configurations also had the highest drag coefficients.

Only small changes in trim C_Y or $(pb/2V)_T$ were noted in these tests (figs. 8 and 9) and there is no apparent effect of varying the store mountings. These data indicate that the presence of the fuselage-mounted stores of these tests did not induce any appreciable unsymmetrical trim loads in the lateral plane.

Buffeting

Parts of the telemeter records of transverse (lateral) acceleration are shown in figure 10 for the three models having completely external stores in order to illustrate the random nature of the buffeting encountered. No buffeting was experienced by the semisubmerged store model up to the test limit of approximately $M = 1.4$. Buffeting was encountered at or near trim conditions throughout the test Mach number range from about 0.7 to 1.4 on each of the models having completely external stores (fig. 11) with the peak buffet intensity in each case near $M = 0.9$. Frequencies near the lower, or mount bending, frequencies were predominant in the transverse plane in the store, with only some small amplitude buffeting in the fuselage as indicated for the tangent store model in figure 11. The very low frequency oscillations appearing in figure 10 are small-amplitude short-period stability oscillations and are not a part of the buffet phenomenon. Although buffeting was recorded in the normal plane of each of the models having completely external stores, the frequencies were generally too high and too random to permit adequate amplitude response corrections; hence, no normal buffet intensity variations with Mach number are presented. However, the maximum normal buffet intensity encountered by the pylon-mounted-store models is believed to be of the order of $\pm 0.5g$ at frequencies of the order of 200 cps. Buffeting in the normal plane of the tangent-mounted-store model is believed to have been approximately of the same order of magnitude as in the lateral plane, but again, the frequencies were too high and too random to permit adequate amplitude response corrections.

Data from reference 1 indicate that no buffeting should be encountered by the basic fuselage and tail configurations of the present investigation within the range of Mach number and normal-force coefficient covered. Data from references 1 and 3 indicate that low-lift buffeting would be expected on the 10-percent-thick pylon at transonic speeds but would not be expected above approximately $M = 1$. Although it is thought that the isolated store should not encounter low-lift buffeting above approximately $M = 1$, the transonic characteristics are less predictable and the possibility of transonic buffeting of the store itself must be recognized.

The transonic buffeting recorded in the tangent-mounted store was roughly three times as severe as in the store mounted on the 10-percent-thick pylon and roughly six times as severe as in the store mounted on the 4-percent-thick pylon. Although the transonic buffeting encountered

in these tests may have been caused partially by buffeting components, these data indicate that mutual interference between the fuselage, store, and pylon may be a predominant factor and that store-body proximity and pylon thickness seriously aggravate this condition. It is believed that the buffeting which occurred on these models at supersonic speeds was induced primarily by mutual interference between the body, store, and pylon.

It is thought that the unfavorable store location relative to the maximum fuselage thickness may have been a large contributing factor in the buffet phenomenon encountered in these tests, but, inasmuch as no different longitudinal store locations have been tested, this factor cannot be evaluated.

Drag

Total drag coefficients based on the maximum fuselage cross-sectional area for each configuration tested are presented in figure 12(a) where they are compared with the drag coefficients of the body-tail configuration of reference 1 (6-percent-thick surfaces). Also shown are the drag coefficients of an isolated store tested in conjunction with this investigation by the helium-gun technique. The drag coefficients of the stabilizing fins have been subtracted from the total drag coefficients of the isolated store in order to obtain the store drag coefficient presented here.

The drag coefficients added to the body-tail configuration by the store assembly plus interference is shown in figure 12(b) based on the actual maximum cross-sectional area of the store. Also shown for comparison are the drag coefficients of the isolated store. The difference between the drag coefficient of the isolated store and the drag coefficient of the stores of the test configurations is primarily due to interference; an exception being a small increment caused by the pylons of models C and D.

The semisubmerged store arrangement was the optimum configuration tested from the drag standpoint because the subsonic drag level was essentially unchanged by the presence of the store, no unfavorable interference drag was indicated at approximately $M = 1.2$, and the interference drag at transonic Mach numbers was generally less than that of the other configurations tested. The tangent-mounted store arrangement was the least desirable configuration tested because the drag added by the store was about four times the isolated-store drag at subsonic speed, about twice the isolated-store drag at approximately $M = 1.2$, and was generally large at transonic Mach numbers. Some relief from this severe interference drag is realized when the store proximity to the fuselage is lessened with a thick (10 percent) pylon, and still further improvement is obtained when the pylon thickness is reduced from 10 percent to 4 percent. These data

indicate that large drag increments due to severe interference effects were present on the completely external-store models tested and that these interference effects were aggravated by store-fuselage proximity and by pylon thickness. No significant differences in the drag-rise Mach number or the shape of the total-drag curves were encountered due to the fuselage-mounted stores of these tests. The transonic drag rise of these configurations is in general agreement with the concept of the transonic area rule in that configurations having similar area distributions had about the same drag rise.

CONCLUSIONS

From the results of flight tests of four wingless models having fuselage-mounted models of a 10,000-pound large-diameter bomb without fins and one isolated-store model having the same shape, the following conclusions are drawn:

1. High-speed low-lift buffeting and large drag increments may be induced by mutual interference between a fuselage, store, and pylon at supersonic Mach numbers when large, low-fineness-ratio stores are mounted on a fuselage near the fuselage maximum diameter.

2. Buffet and drag characteristics of external fuselage-mounted stores may be adversely affected by fuselage-store proximity and by pylon thickness. A semisubmerged store arrangement experienced no buffeting and had the smallest interference drag of any of the configurations tested. An external store mounted tangent to the fuselage was characterized by severe buffeting at transonic speeds and by a large interference drag increment throughout the test Mach number range.

3. No severe or abrupt trim changes may be attributed to the store configurations tested. A trend toward zero or positive subsonic trim normal force was evidenced by all configurations tested.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., October 6, 1953.

REFERENCES

1. Mason, Homer P., and Gardner, William N.: An Application of the Rocket-Propelled-Model Technique to the Investigation of Low-Lift Buffeting and the Results of Preliminary Tests. NACA RM L52C27, 1952.

2. Hall, James Rudyard: Comparison of Free-Flight Measurements of the Zero-Lift Drag Rise of Six Airplane Configurations and Their Equivalent Bodies of Revolution at Transonic Speeds. NACA RM L53J21a, 1953.

3. Humphreys, Milton D.: Pressure Pulsations on Rigid Airfoils at Transonic Speeds. NACA RM L51I12, 1951.

TABLE I.- FUSELAGE AND STORE COORDINATES

(Stations and radii in inches)

Fuselage	
Station	Radius
0	0
2.5	.508
5.0	.979
7.5	1.413
10.0	1.810
12.5	2.170
15.0	2.493
17.5	2.779
20	3.028
22.5	3.241
25	3.416
27.5	3.550
30.0	3.656
32.5	3.721
35.625	3.750
40	3.722
42.5	3.680
45	3.620
47.5	3.541
50	3.444
52.5	3.329
55	3.196
57.5	3.043
60	2.872
62.5	2.683
65	2.475
67.5	2.249
70	2.004
72.5	1.741
75.187	1.438

Store	
Station	Radius
0	0
0.0471	0.2101
.0942	.2990
.2349	.4783
.4710	.6834
1.1775	1.0906
2.3549	1.5217
3.5330	1.8049
4.7099	1.9943
5.8874	2.1142
7.0648	2.1801
8.2423	2.2034
8.4375	2.2038
9.6010	2.1871
10.7645	2.1370
11.9279	2.0538
13.0914	1.9385
14.2549	1.7927
15.4184	1.6186
16.5818	1.4194
17.7453	1.1984
18.9389	.9553
20.0727	.7087
21.2358	.4503
22.3321	.2057
22.5000	0
L. E. radius: 0.4537 T. E. radius: 0.2099	
Note: Fair aft portion to remove cusp by straight line.	

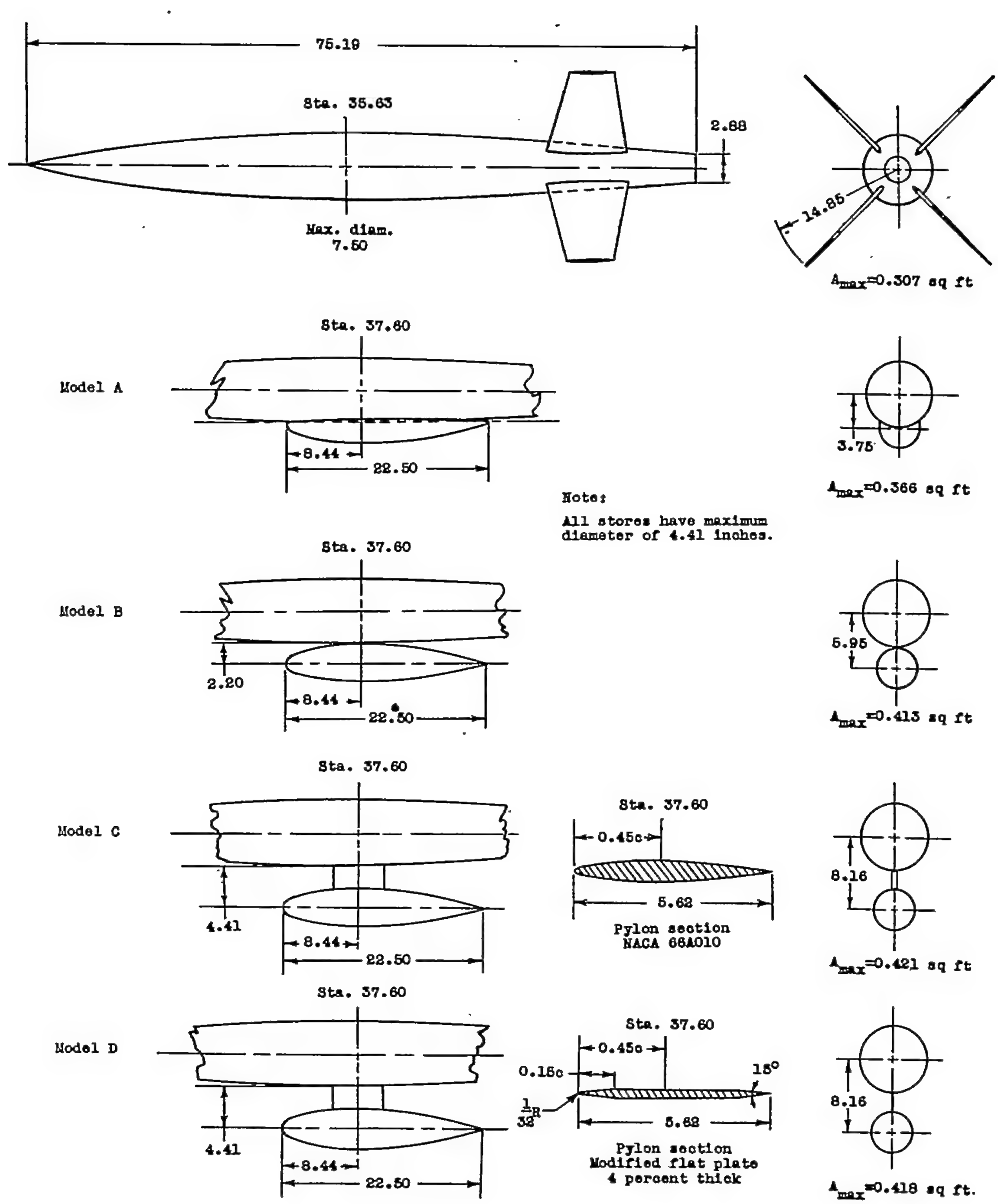


Figure 1.- Principal dimensions of fuselage-mounted store configurations. (All dimensions are in inches unless shown.)

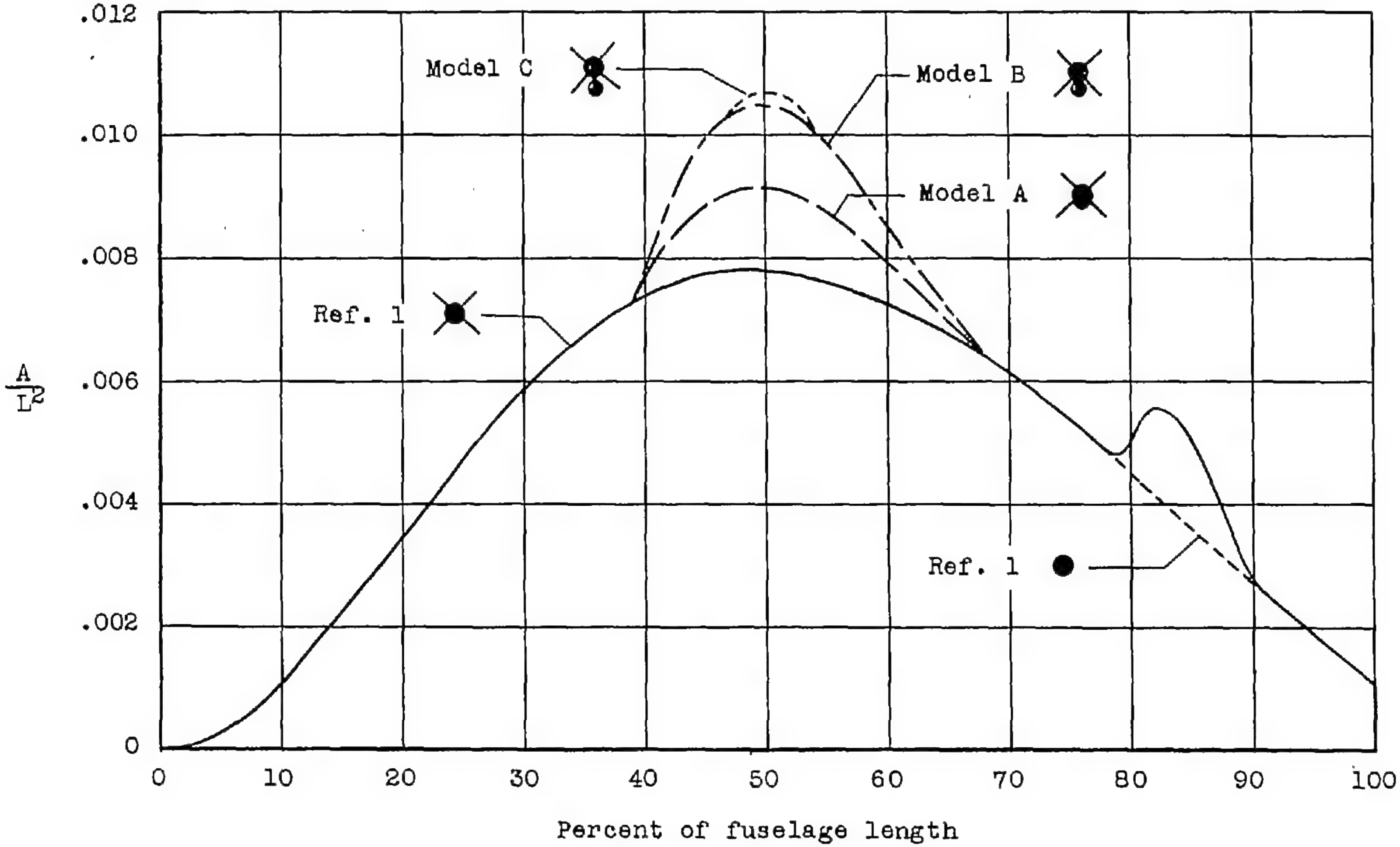
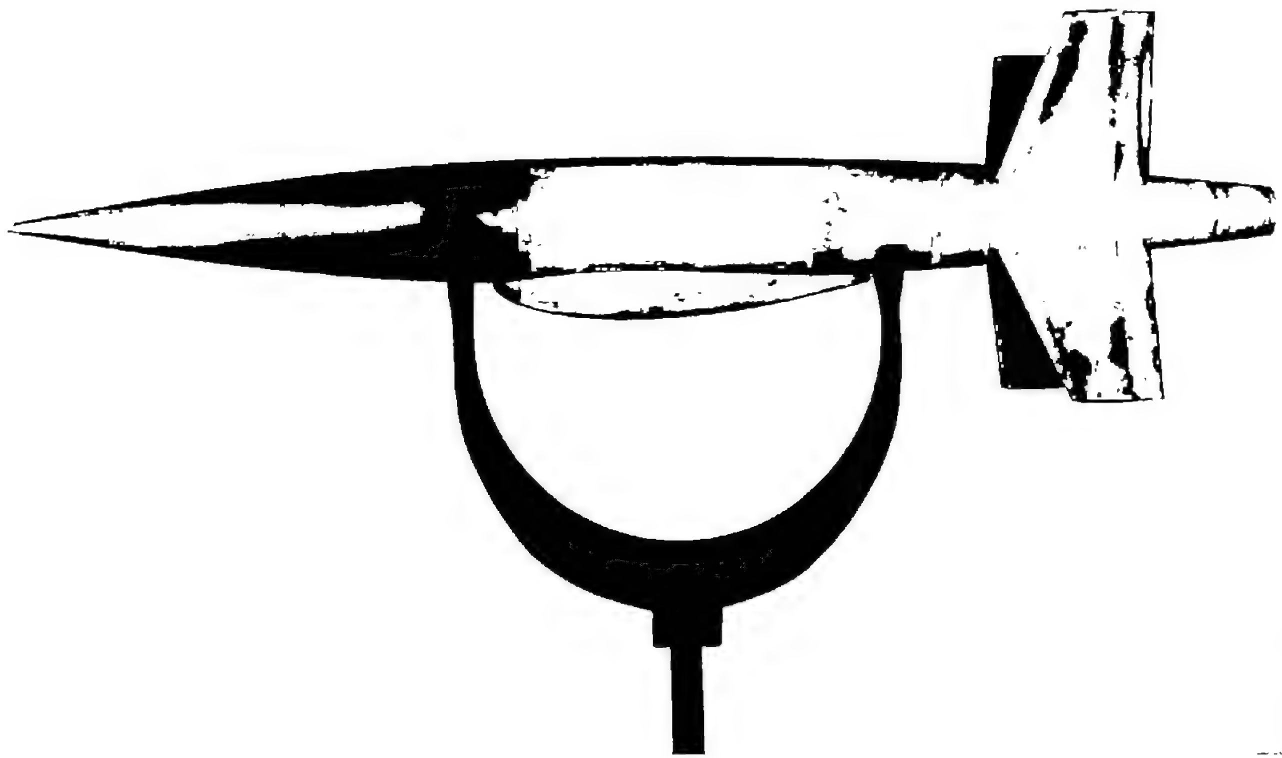


Figure 2.- Longitudinal distribution of cross-sectional area.



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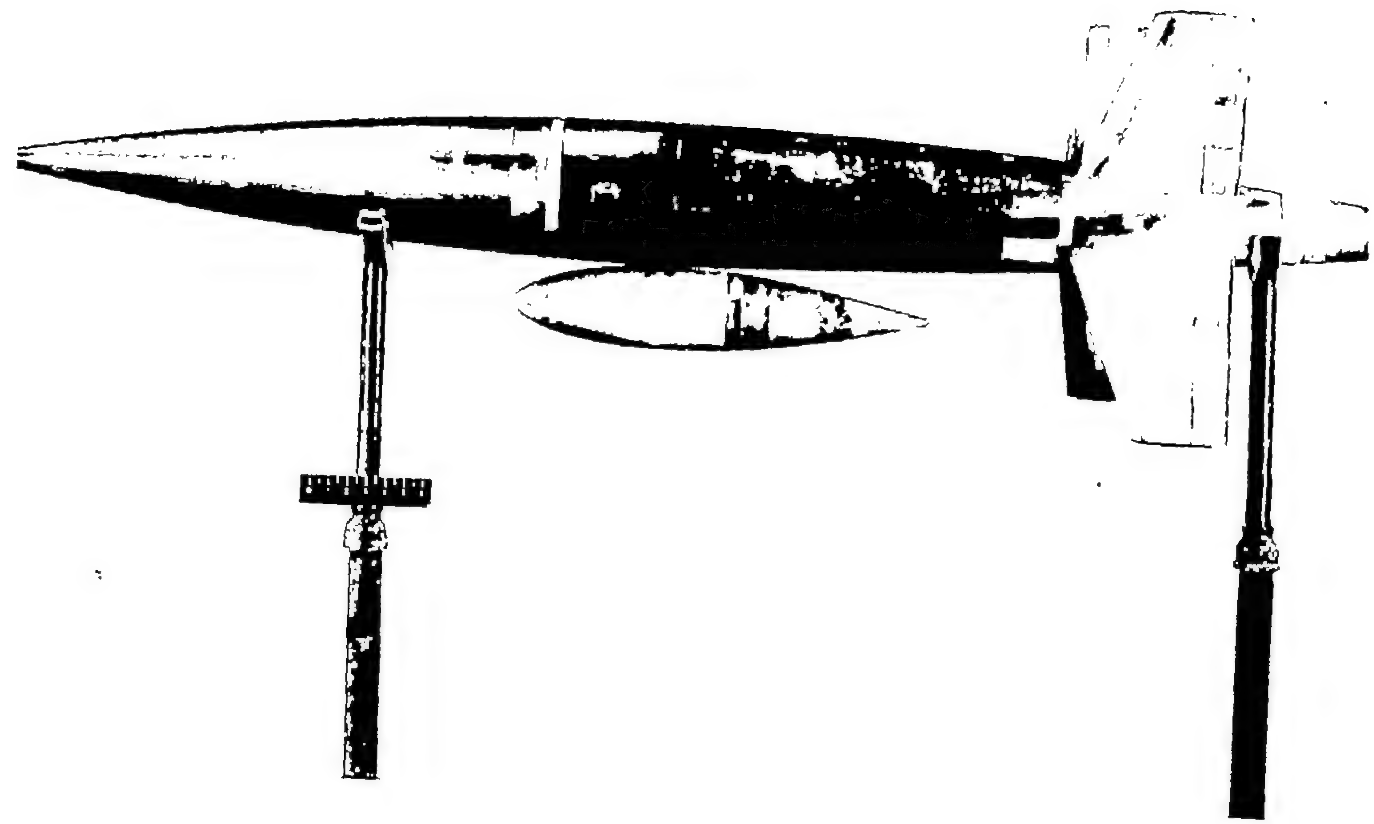
(a) Model A.

Figure 3.- External-stores buffet-research models.



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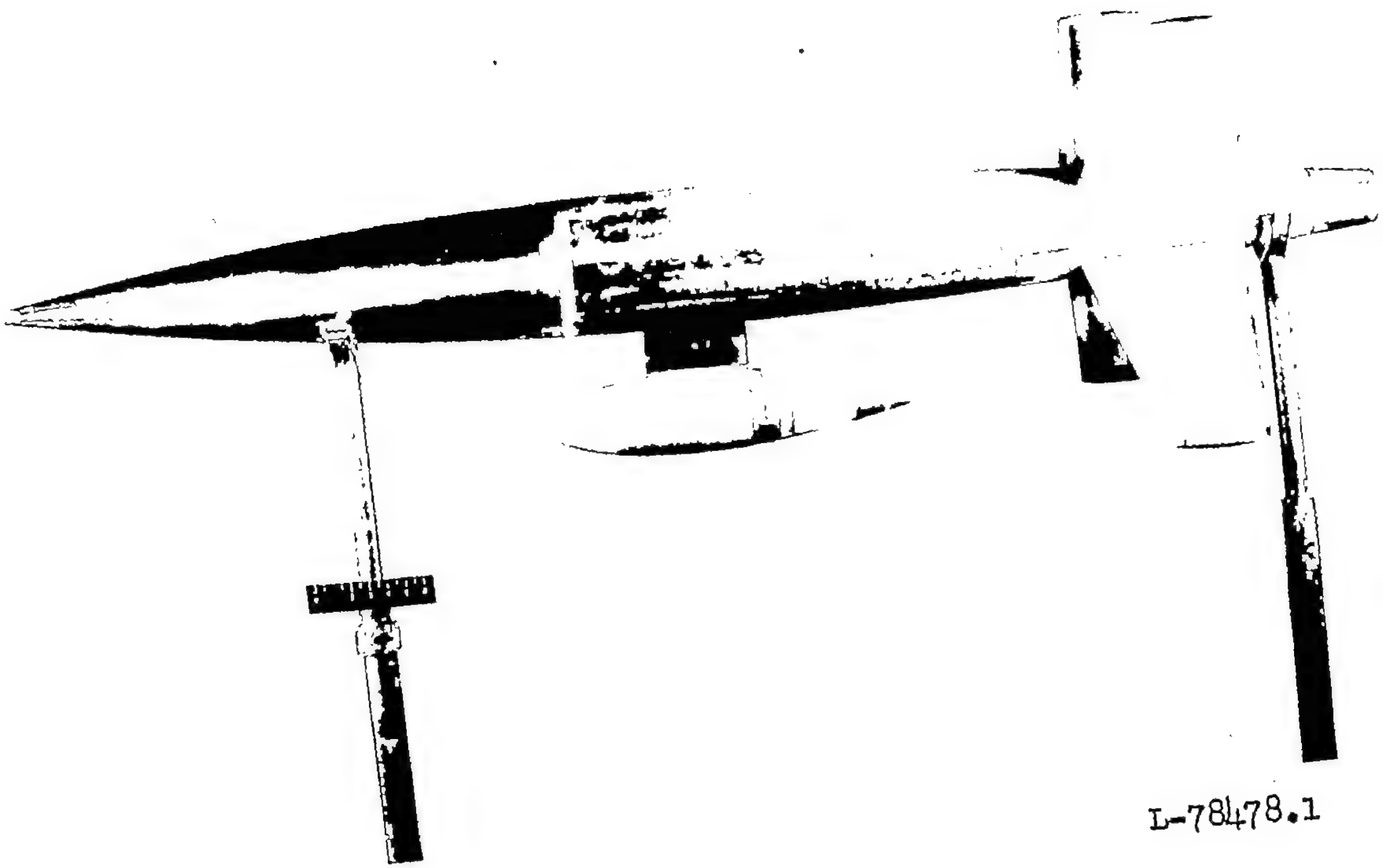
(b) Model B.

Figure 3.- Continued.



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(c) Model D.

Figure 3.- Continued.

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(d) Isolated-store model used in helium-gun tests.

Figure 3.- Concluded.

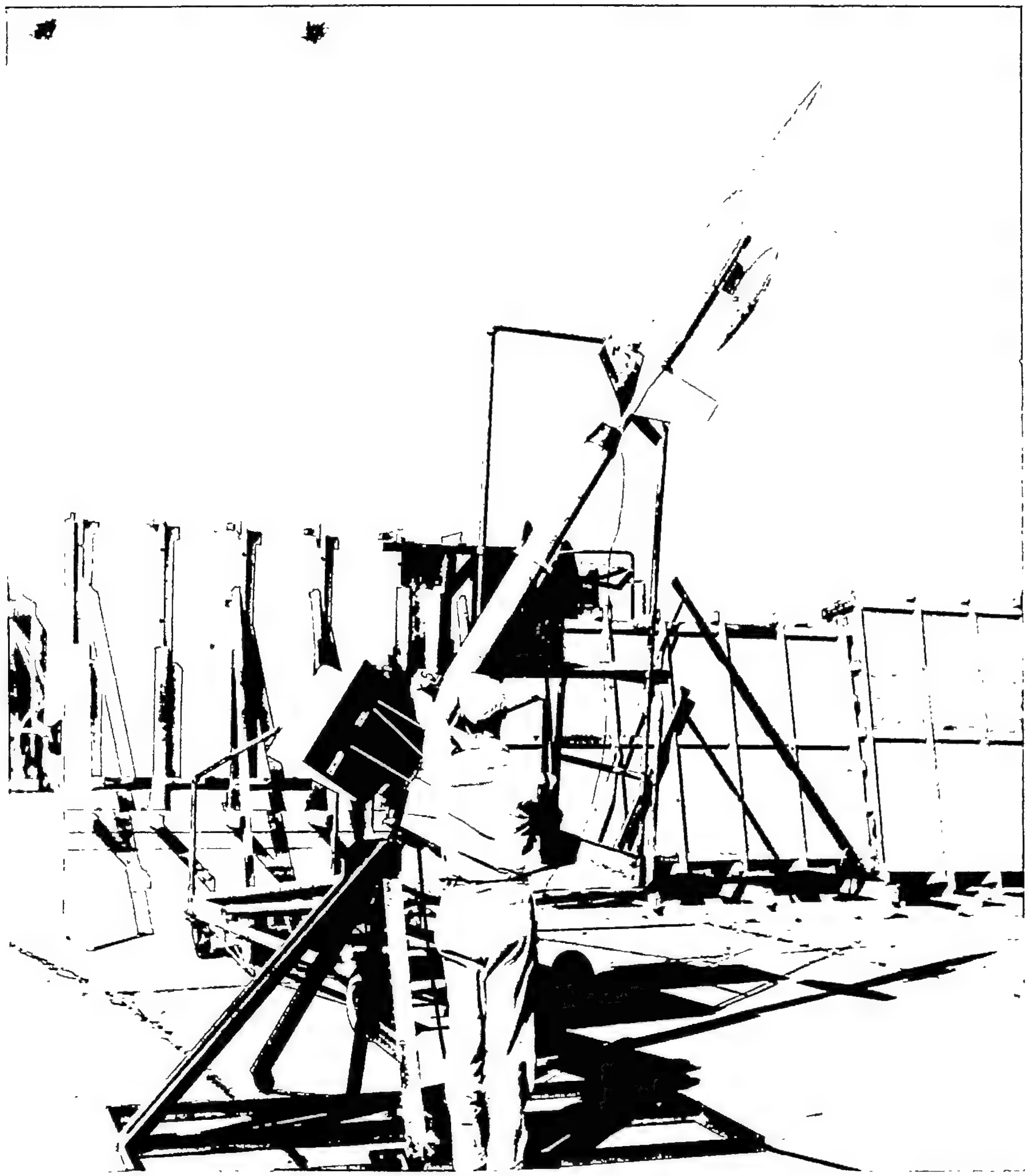

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Figure 4.- External-store buffet-research model (model C) and booster on the rail launcher.

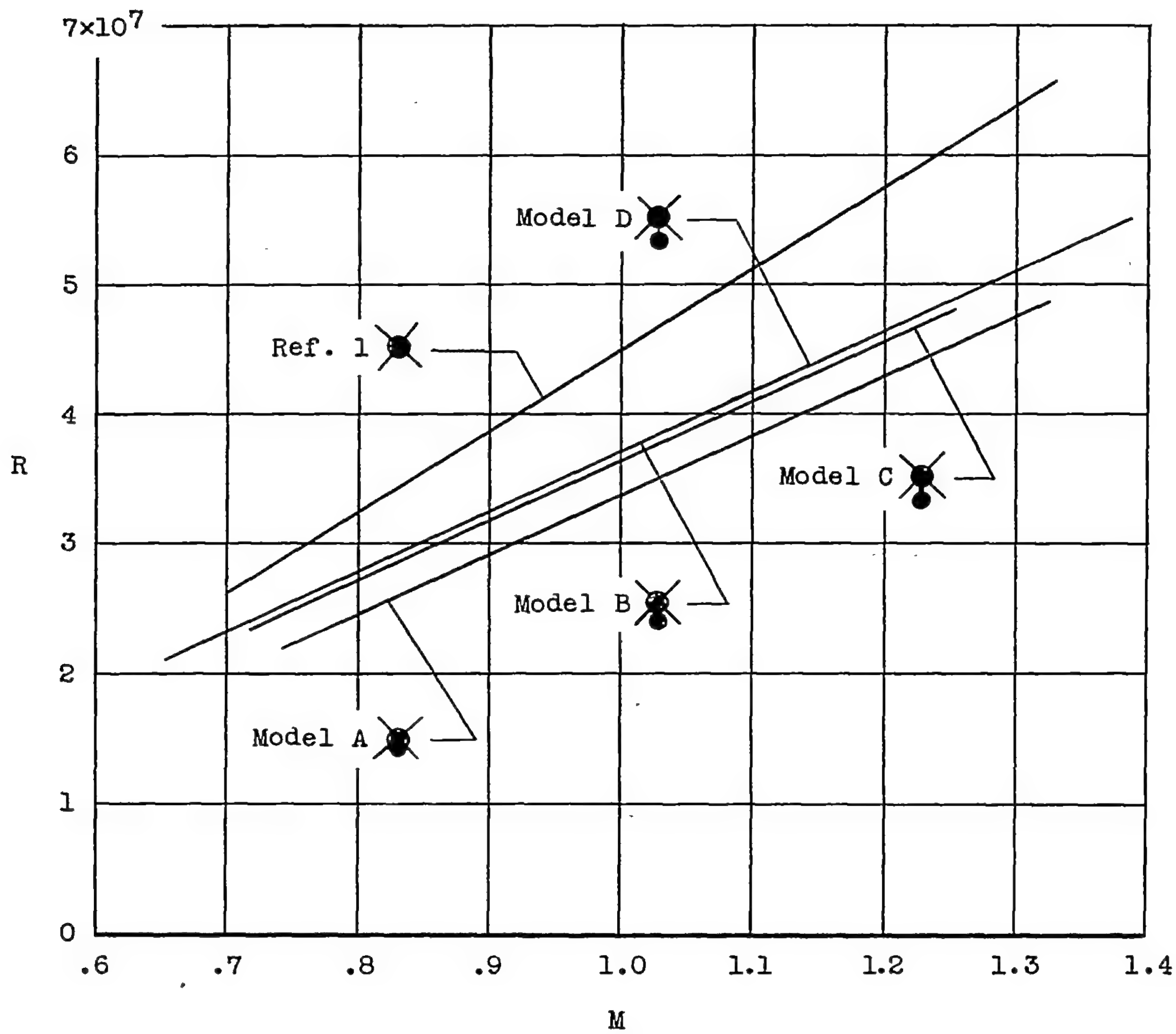


Figure 5.- Variation of Reynolds number, based on fuselage length, with Mach number.

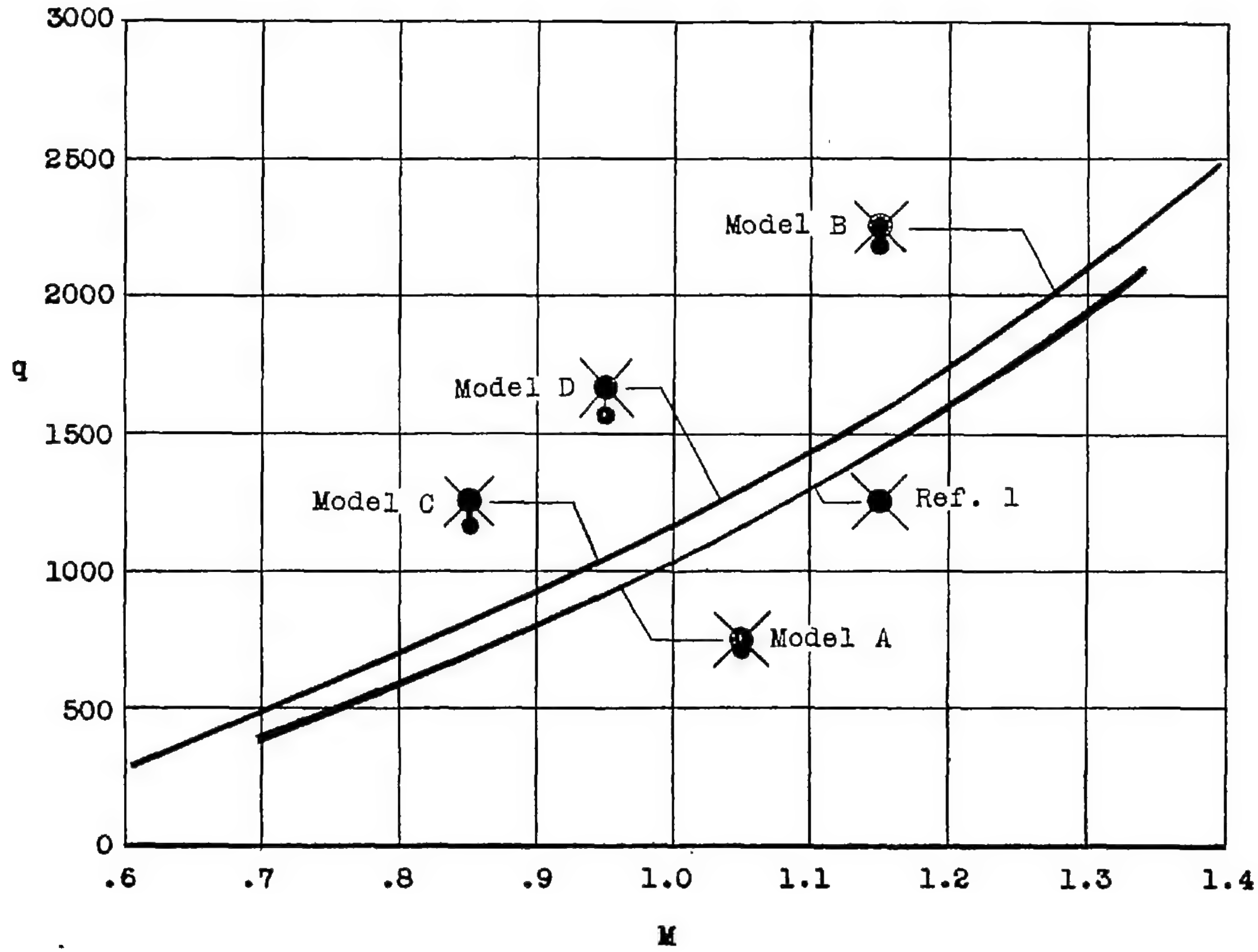


Figure 6.- Variation of dynamic pressure with Mach number. (Dynamic pressure is in pounds per square foot.)

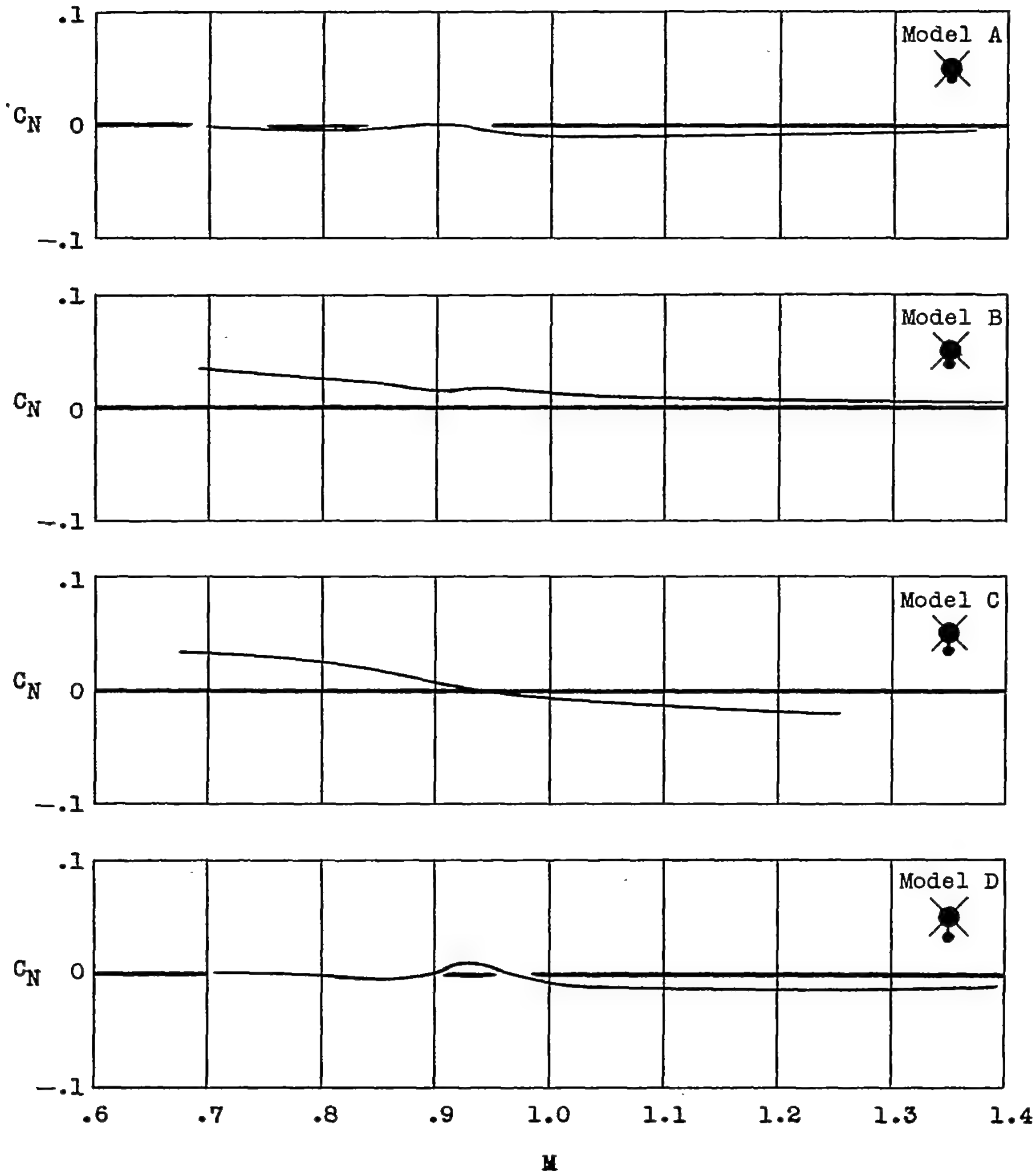


Figure 7.- Variation of trim normal-force coefficient with Mach number.

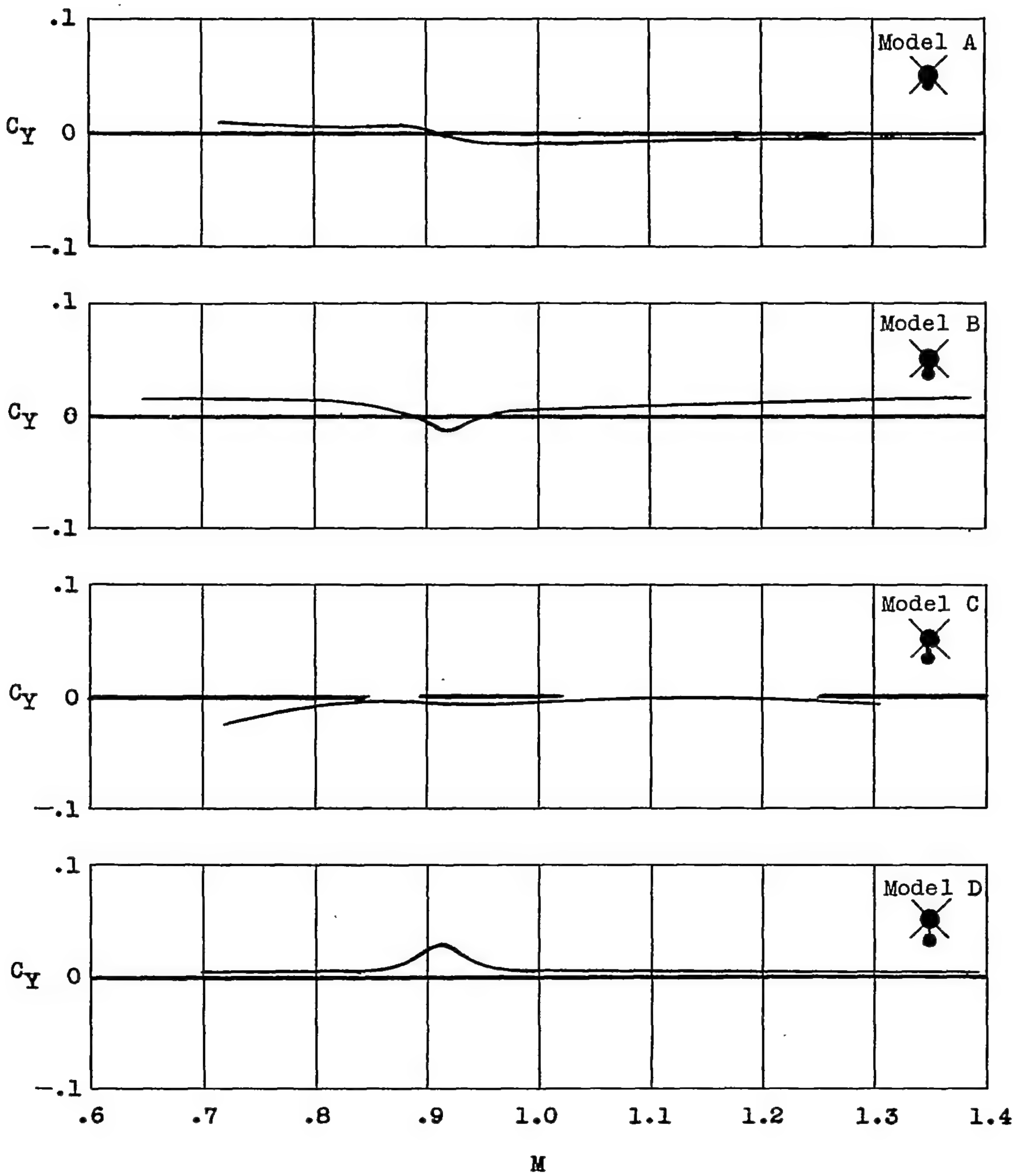


Figure 8.- Variation of trim side-force coefficient with Mach number.

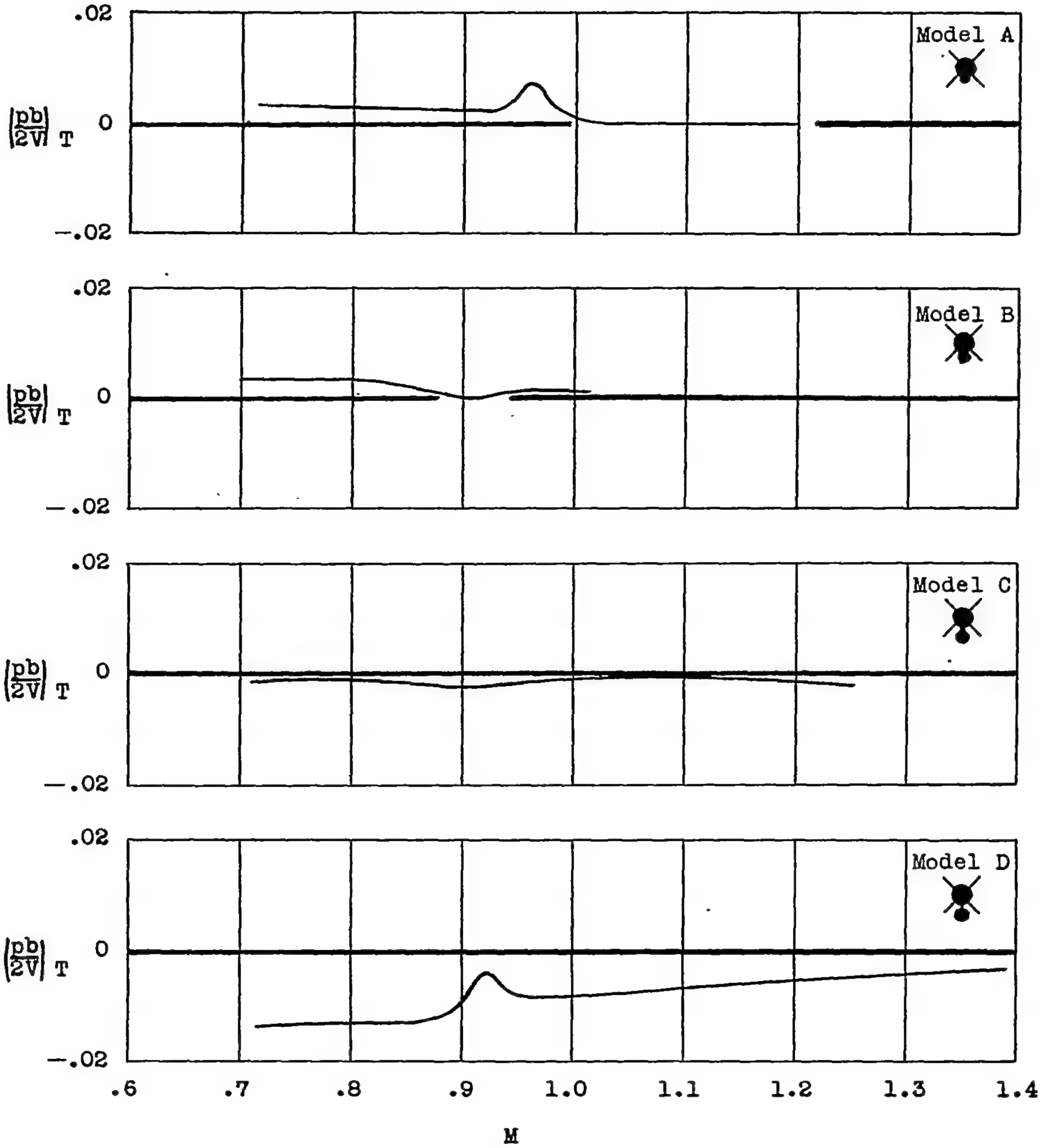
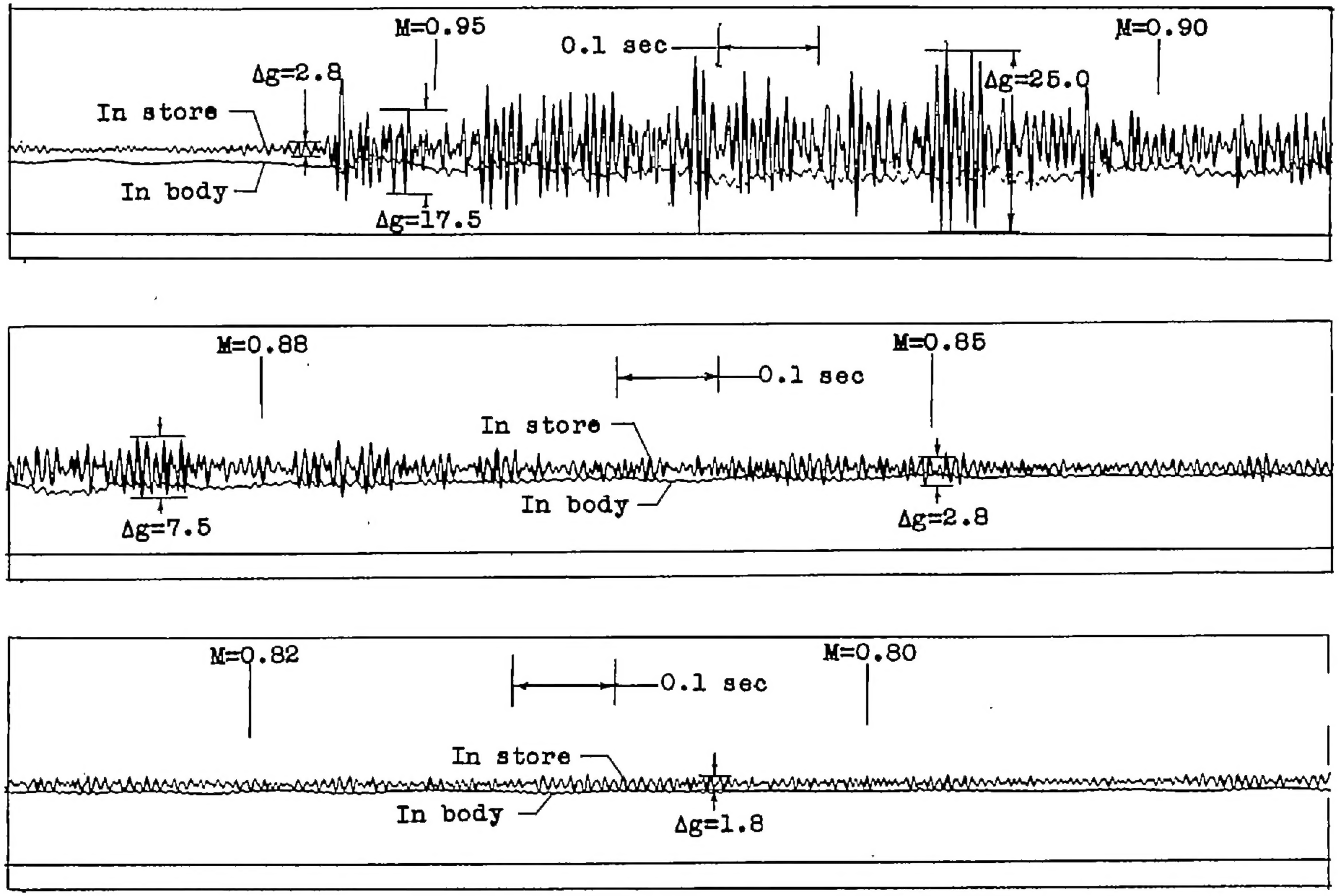


Figure 9.- Variation of trim helix angle of tail with Mach number.

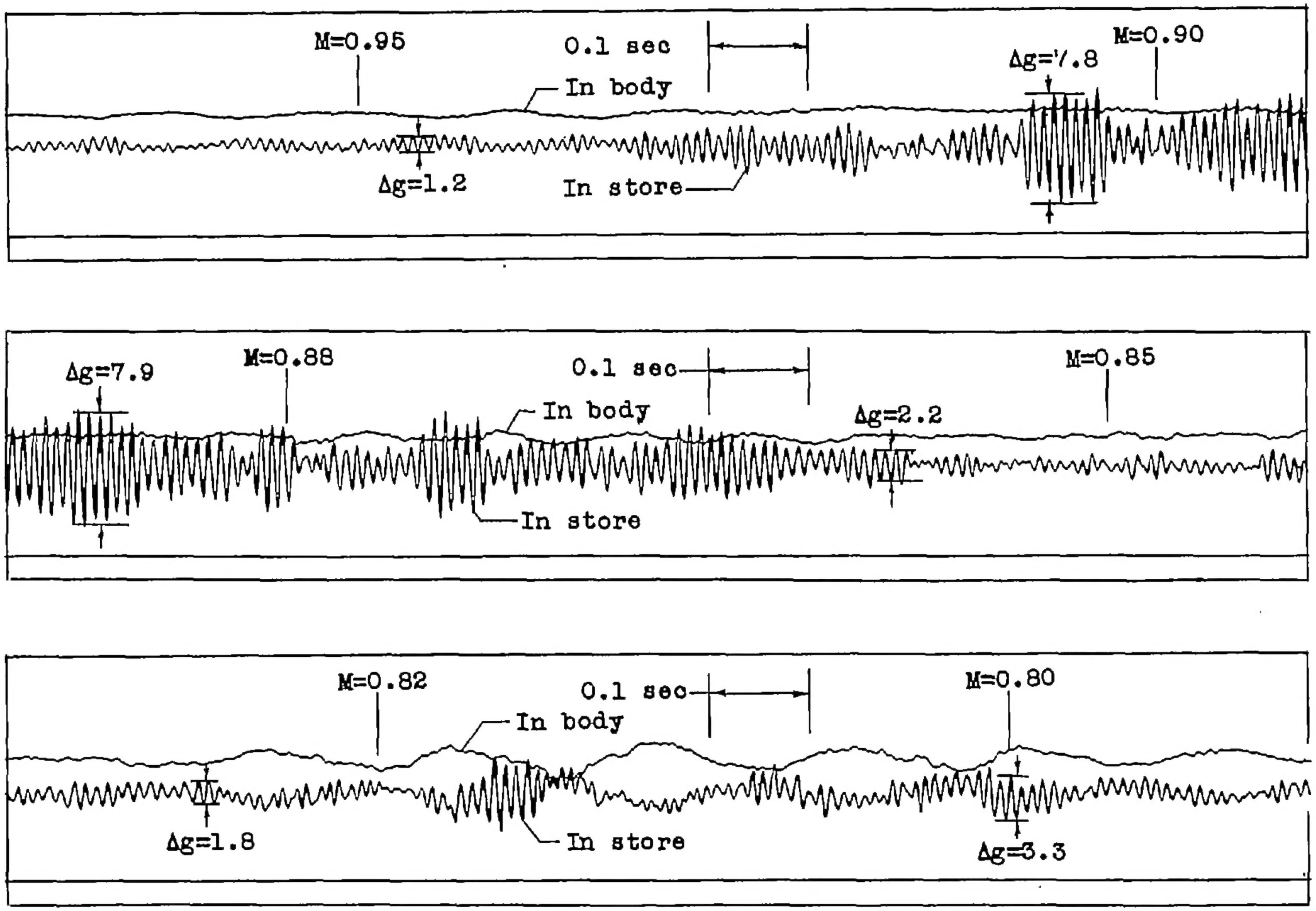
[redacted]



(a) Tangent mounted store; model B.

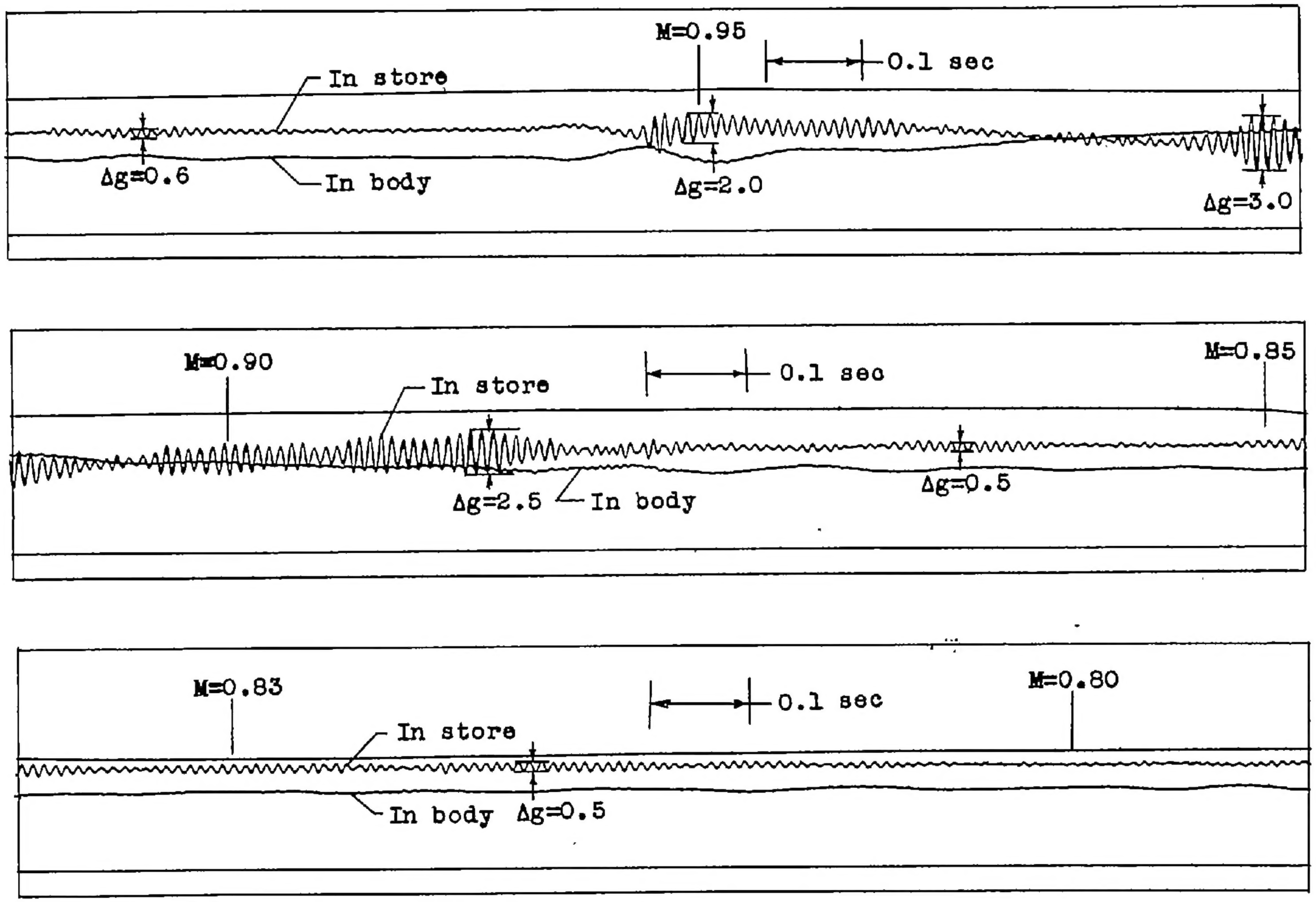
Figure 10.- Parts of telemeter records of transverse acceleration during buffeting.

[redacted]



(b) Store on 10-percent-thick pylon; model C.

Figure 10.- Continued.



(c) Store on 4-percent-thick pylon; model D.

Figure 10.- Concluded.

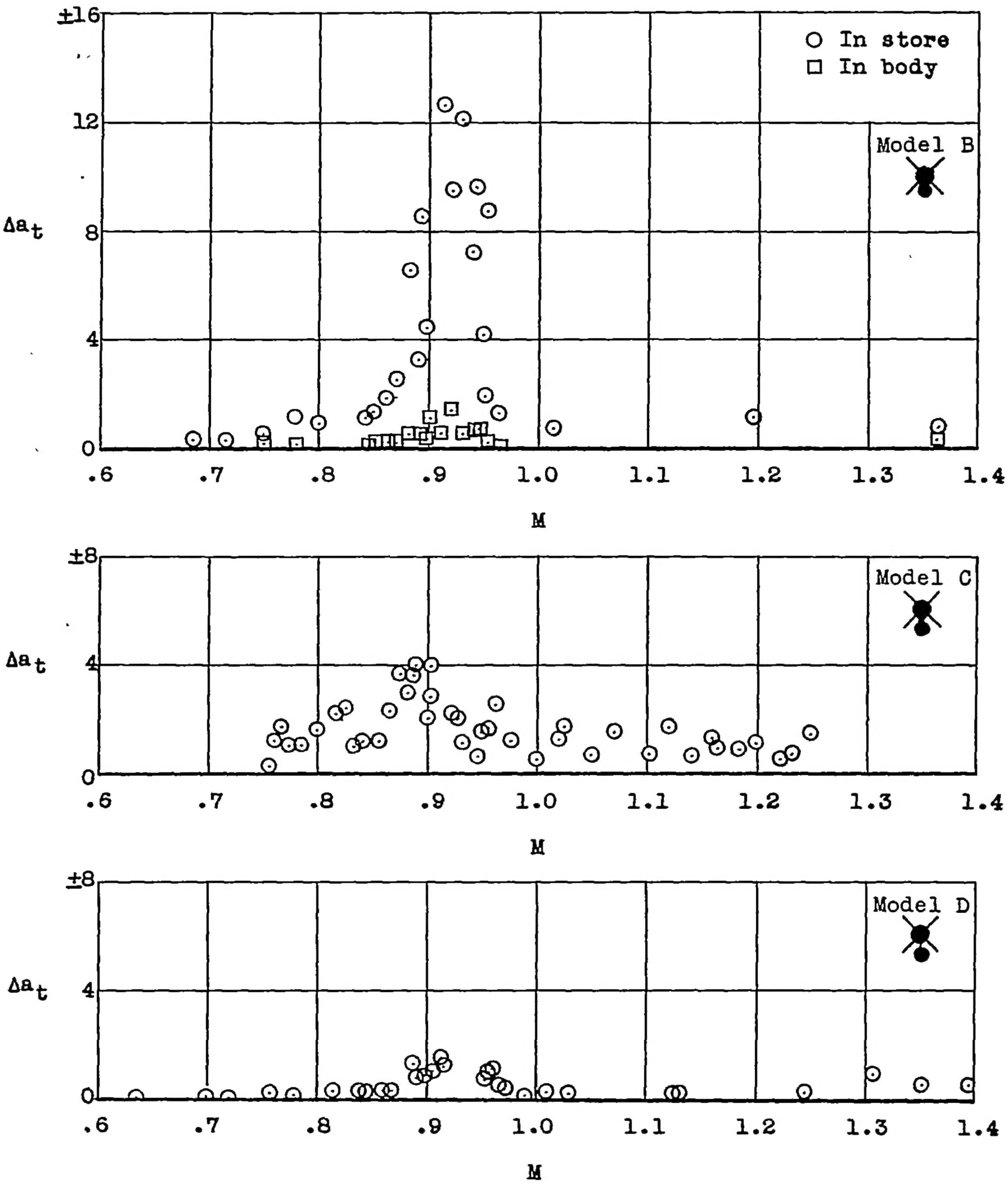


Figure 11.- Variation of transverse buffet intensity in the store and body with Mach number.